Nonlinear unbalanced Bessel beams (NL-UBBs) in the filamentary dynamics of self-focusing Gaussian beams

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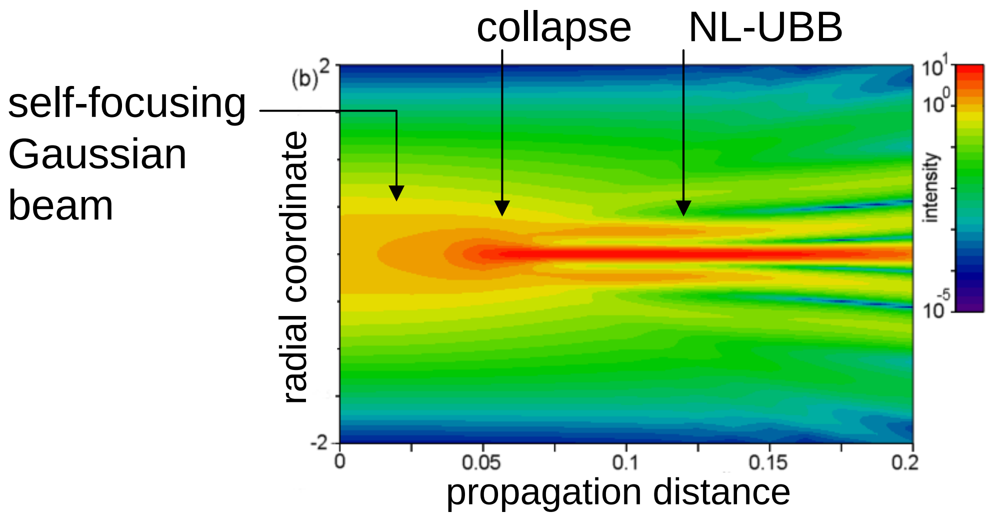
NLSE $\longrightarrow$ $$\partial_\xi A = \frac{i}{2}\Delta_\rho A + \underbrace{ig|A|^2 A}_{\text{Kerr}} - \underbrace{\gamma|A|^{2K-2} A}_{\text{NL losses}}$$

- Strong self-focusing and collapse of a Gaussian beam arrested by a small amount of nonlinear losses leads to the formation of a NL-UBB.



- NLUBB: light beam that can propagate without diffraction and without attenuation in a nonlinear medium with nonlinear losses (loss-resistant).
- This suggests that conical waves as NL-UBB could be involved in light filaments.

1) What is a NL-UBB?

It is a monochromatic light beam which is a) diffraction-free

b) disipation-resistant

Kerr NL losses

NLSE $$\partial_\xi A = \frac{i}{2}\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial A}{\partial\rho}\right) + ig|A|^2A - \gamma|A|^{2K-2}A$$

$$A(\rho,\xi) = \underbrace{a(\rho)e^{i\varphi(\rho)}}_{\text{stationary amplitude and phase radial profile of NL-UBB of peak intensity } I = a^2(0)} e^{-i\delta\xi}$$

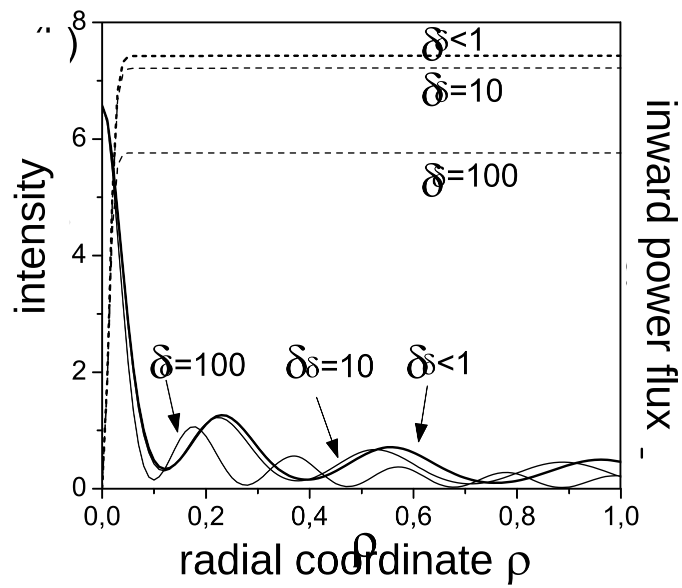
nonlinear axial phase shift associated to a cone angle $\theta = (\delta/2k)^{1/2}$

Bessel-like radial profiles with inifinite power

$$\frac{1}{\rho}\frac{d}{\rho}\left(\rho\frac{da}{d\rho}\right) - a\left(\frac{d\phi}{d\rho}\right)^2 + 2\delta a + 2ga^3 = 0$$

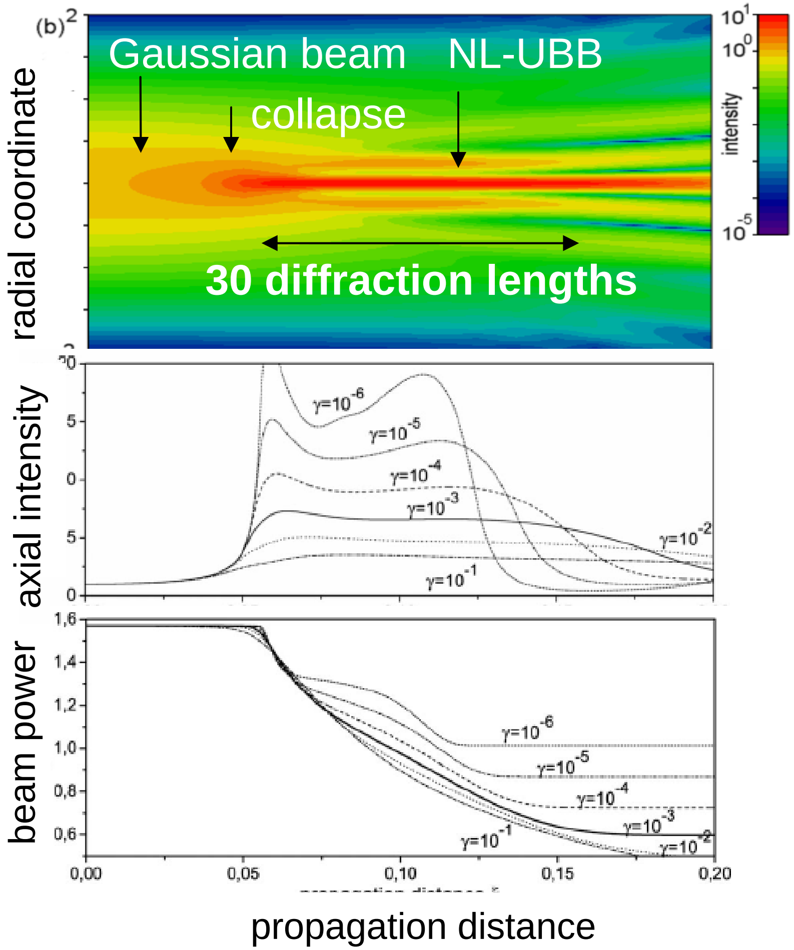
Refilling mechanism for stationarity with NLLs

$$\underbrace{-2\pi\rho a^2\frac{d\phi}{d\rho}}_{\text{inward radial power flux}} = \underbrace{2\gamma 2\pi\int_0^\rho d\rho\rho a^{2K}}_{\text{nonlinear losses}}$$

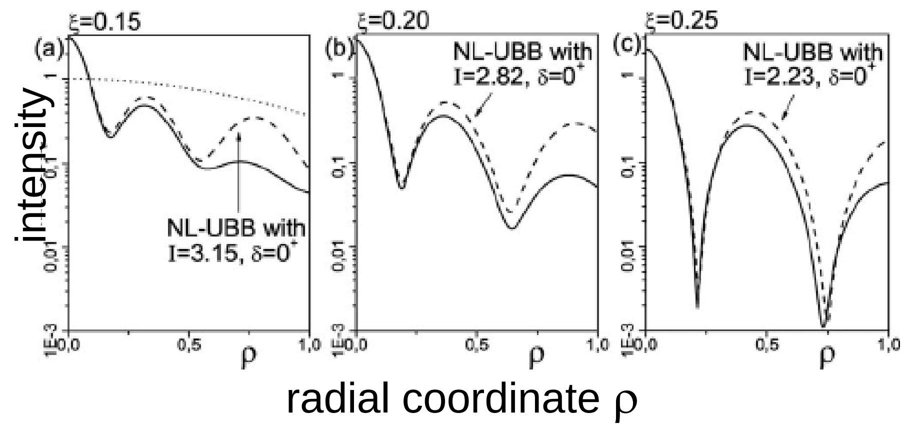


2) Spontaneous generation of NL-UBB upon self-focusing of Gaussian beams

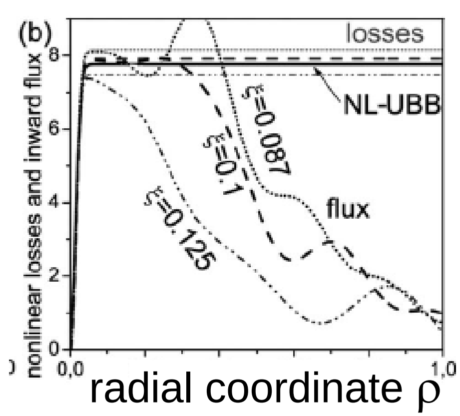
Conditions for NL-UBB formation upon collapse of Gaussian beam:
self-focusing length << diffraction length << nonlinear loss length,
i.e. strong self-focusing with initially negligible NLLs



radial intensity profile at increasing distances



inward radial power flux



More information at:

M.A. Porras, A. Parola, Opt. Lett. 33, 1738 (2008)

S. Polyakov et al, JOSA B 18, 1981 (2001)